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Deceleration versus acceleration universe in different frames of $F(R)$ gravity

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ABSTRACT

In this paper we study the occurrence of accelerating universe versus decelerating universe between the $F(R)$ gravity frame (Jordan frame) and non-minimally coupled scalar field theory frame, and the minimally coupled scalar field theory frame (Einstein frame) for various models. As we show, if acceleration is imposed in one frame, it will not necessarily correspond to an accelerating metric when transformed in another frame. As we will demonstrate, this issue is model and frame-dependent but it seems there is no general scheme which permits to classify such cases.

1. Introduction

One of the most profound questions in modified gravity is related with the choice of the physical frame. The frame corresponding to $F(R)$ gravity [1] is called Jordan frame, and by a conformal transformation it can be transformed to a minimally coupled scalar–tensor theory, with the corresponding frame being called Einstein frame. In addition to these, there are also frames in which the scalar field is non-minimally coupled to gravity, and these can be reached by a $F(R)$ gravity by also using a suitably chosen conformal transformation, or directly by the Einstein frame theory by conformally transforming the theory.

Generally speaking, one should confront the theoretical predictions of a specific gravitational theory with the observable Universe history supported by the current observational data. In this sense, each of the three mentioned frames, namely the $F(R)$ gravity, and the minimal and non-minimal scalar theories, may give a viable description of the observable Universe history. However, it is not sure that a viable description in one frame gives also viable and convenient description in the other frame. For instance, it may give a viable but physically inconvenient description. In other words, there appears the question which of these three frames is the most physical one (and in which sense) or, at least, which of these frames gives a convenient description of the Universe history. Eventually, the answer to this question depends very much from the confrontation with the observational data, from the specific choice of the theory and from the observer associated with specific frame. At the same time, the related question is about equivalent results in all three frames and/or about construction of the observable quantities which are invariant under conformal transformations between the three frames.

In the study of the inflationary epoch, when one is dealing with quasi-de Sitter space, it is expected that the spectral index of primordial curvature perturbations and the scalar-to-tensor ratio calculated in two frames ($F(R)$ and minimal scalar–tensor) are nearly the same. Indeed, the equivalence of two frames was explicitly demonstrated in Refs. [2] and also in [3]. However, this is surely not enough for number of reasons. For example, for the effect on neutron stars in $F(R)$ gravity, the Jordan and Einstein frame pictures are different, as was shown in Ref. [4].

In addition, finite-time singularities [5–9] between Jordan and Einstein frames belong to different types of singularity, see for example [8,10], because the conformal transformation does not work for singular points. In this research line, in this paper we shall investigate under which circumstances, an accelerating evolution in one frame may be transformed to a decelerating evolution in the other frame. We shall consider three types of frames, namely the

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